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(54) Title: LIGHT REFLECTANT SURFACE FOR LUMINAIRES (57) Abstract <p>The present invention relates to surfaces used to reflect light, and particularly to highly light reflectant surfaces that provide even diffusion of light for the purpose of maximizing light efficiency and/or uniformity in a luminaire. By employing an expanded polytetrafluoroethylene (PTFE) comprising a microstructure of polymeric nodes and fibrils, the material of the present invention demonstrates exceptional diffuse reflectivity across a wide spectrum of visible light. Additionally, the material of the present invention provides many properties that have been previously unavailable in highly diffuse reflective material, including a high degree of malleability, moldability and flexibility, and effective reflectivity even at relatively thin cross sections.</p>		

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TITLE OF THE INVENTION

LIGHT REFLECTANT SURFACE FOR LUMINAIRES

RELATED APPLICATIONS

5 The present application is a continuation-in-part of copending United States Patent Application Serial No. 08/369,850, filed January 6, 1995.

BACKGROUND OF THE INVENTION**1. Field of the Invention**

10 The present invention relates to surfaces used to reflect light, and particularly to highly light reflectant surfaces that provide even diffusion of light for the purpose of maximizing efficiency and/or light uniformity.

2. Description of Related Art

15 The present invention generally relates to the field of lighting, and more particularly to luminaires which utilize a reflector for redirecting light. The term "luminaire" as used herein is meant to describe a complete lighting unit consisting of a lamp or lamps together with components designed to redirect and distribute light from the lamp(s), along with a housing which positions and protects the lamp(s) and components.

20 Luminaires can be categorized by numerous methods. Typically, there are indoor and outdoor luminaire applications. Indoor luminaires can be categorized by light output emitted above and below the horizontal. The Commission Internationale de l'Eclairage (CIE) has various luminaire classifications. These are direct, semidirect, general diffuse, semi-indirect, and indirect. Direct lighting defines light that is at least 90% below the horizontal. Semidirect lighting is predominantly downward at 60-90% of the light below the horizontal. General diffuse light describes output where the downward and upward components are about equal. Semi-indirect are predominantly upward with 60-90% of the light above the horizontal. Indirect lighting describes
25 systems are those where 90-100% of the light is directed toward the ceiling and upper side walls. Within these categories, there are many applications. Some typical applications include recessed luminaires such as fluorescent troffers, incandescent downlighting, and high intensity discharge (HID) downlighting. There are also ceiling-mounted luminaires, track mounted, wall-mounted,
30 suspended, and portable luminaires.
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 Outdoor luminaires can be categorized by similar methods. Light distribution of luminaires is categorized by the Illuminating Engineering Society of North America (IESNA) into five light distribution types. These range from

narrow symmetrical distribution to wide non-symmetrical patterns. Some typical applications include pole-mounted luminaires, surface-mounted luminaires, bollard luminaires, and floodlight luminaires.

5 Other luminaire applications include luminaires for automotive lighting such as head lights, tail lights, daytime running lights, interior lights, instrument panel lights, etc. There are also unique applications such as backlights for liquid crystal displays and light boxes which can be used for a range of inspection needs such as x-ray viewers, tracing tables, etc.

10 Light sources which are used in the above listed luminaire applications include but are not limited to incandescent filament lamps, fluorescent lamps, high intensity discharge lamps (HID), arc lamps, electrodeless lamps, electroluminescent lamps, light-emitting diodes (LED), nuclear light sources, gaslights, etc.

15 In virtually all of the luminaire applications mentioned above, light is redirected by the use of a reflective material. The reflection characteristics of these materials can be described as being either specular, diffuse, or a combination thereof. While good mirrored surfaces can provide nearly perfect reflectivity of visible light, the light energy exiting these surfaces does so only at an angle equal to the incident angle of light contact. This type of reflection is referred to as specular reflectance. For many applications it is important that
20 light be reflected with an even distribution of light from the surface. This latter property is referred to as diffuse or "lambertian" reflectance.

Throughout the years, reflective materials for luminaires have been studied, optimized, and specified. Specular materials are typically used in
25 luminaires which are designed to preferentially deliver focused light to specific locations. Diffuse materials are more typically used for even dispersion of light having uniform characteristics without the undesirable high and low intensity light areas which are typically generated through the use of specular reflectors. This is desirable for many applications such as work and home locations where even lighting is preferred. Various methods of utilizing these type of diffuse reflectors are discussed, for example, in U.S. Patents 5,192,128 and 5,378,965. There are also many designs which use both specular and diffuse materials to take advantage of both types of reflective characteristics, such as
30 in U.S. Patents 5,051,878 and 5,075,827.

35 In other applications a diffuse reflector coupled with a fresnel lens is utilized to create a uniform directed beam. This is discussed in U.S. Patent 4,504,889.

In still other applications, a diffuse reflector is used in conjunction with diffusers, lenses, or louvers to preferentially direct the light emitting from the luminaire to specific areas. A diffuser scatters the light exiting the luminaire. A lens typically incorporates a series of prisms to preferentially light specific areas of its field of view. A louver is an array of open cells, the walls of which form reflectors. Any of these diffusers, lenses, or louvers can be utilized to redirect light in a wide range of applications such as 2 x 4 foot fluorescent troffers as well as low and high bay HID warehouse luminaires.

Due to the many requirements, the diffuse reflective material choices are relatively few. The most commonly used diffuse reflective materials are diffuse aluminum, white synthetic enamel paint, and white porcelain enamel paint. According to the Illuminating Engineering Society of North America, these three materials exhibit the highest diffuse reflectance through the listed visible wavelengths of 400 nm, 500 nm, and 600 nm. In these wavelengths, diffuse aluminum ranges from 75-84% reflection, white synthetic enamel paint ranges from 48-85% reflection, and white porcelain enamel paint ranges from 56-84% reflection.

Under these criteria, these typical diffuse reflective materials have a visible reflectance maximum of only 85%. At this reflectance level, 15% of the light which impinges upon the reflector is not utilized. Furthermore, in many applications which use diffuse reflectors, there can be additional loss of light stemming from the multiple reflections which are inherently created with diffuse reflective materials. Depending upon the design of the luminaire and the reflector geometry, there can be as many as fifteen or more multiple reflections of a ray of light before it exits the luminaire. At each reflection point, there is a cumulative loss of light associated with the reflection efficiency of the material. Thus an increase of reflectance efficiency of only a few percent can yield an overall luminaire output increase of as much as 10% to 20% or higher.

It is further evident that the percent reflection of each material listed varies significantly within its own measured visible wavelengths of 400nm, 500nm and 600nm. This variation can introduce an undesirable color shift between the incident and reflected light. Thus the optimum diffuse reflective material for luminaire applications is one that has consistently high reflectance throughout the visible spectrum.

Due to the many different applications that exist for reflectant materials, it is not surprising that there are many different commercially available products with a variety of diffuse reflective properties. Until the present invention, the highest reflectance material known with excellent diffuse reflectivity was that

described in United States Patent 4,912,720 and sold under the trademark SPECTRALON by Labsphere, Inc., North Sutton, NH. This material comprises lightly packed granules of polytetrafluoroethylene that has a void volume of about 30 to 50% and is sintered into a relatively hard cohesive block so as to maintain such void volume. Using the techniques taught by United States Patent 4,912,720, it is asserted that exceptionally high diffuse visible light reflectance characteristics can be achieved with this material, with reflectance over previously available reflectant material increasing from 97% to better than 99%.

Despite the reported advantages of SPECTRALON material, it is considered quite deficient in many respects. First, this material comprises a relatively hard block of material that must be carefully carved or machined to desired shapes and dimensions and it is only available in a maximum size of 30.5 cm x 30.5 cm. This severely limits how and where this material can be used and greatly increases the cost of using this material in many applications, especially where large single piece reflectors are desired. Therefore, where a pliable material is desired (such as with reflectors for fluorescent troffers), the SPECTRALON material plainly is inadequate. Furthermore, the additional machining process provides yet another source for contamination that can be detrimental to its reflective properties.

Second, the SPECTRALON material is apparently limited, both structurally and in its ability to reflect light, to a relatively thick minimum depth (i.e., a thickness of greater than 4 mm). Again, this serves to limit where and how this material can be used. Moreover, this limitation tends needlessly to increase both the amount of material required for a given application as well as the weight of the material required for such application.

Third, the SPECTRALON material is apparently relatively expensive to manufacture and purchase. These costs are only increased by the material's difficulty in processing into the final shape from the hard form (i.e., excessive amounts of material may have to be machined away and discarded during production) and its minimum thickness requirements. As a result, the SPECTRALON material is too expensive to be used in many applications that might otherwise benefit from its reflective properties.

Other materials currently used for coating reflective cavities are reflective paints or coatings based on barium sulfate, magnesium oxide, aluminum oxide, titanium oxide, and other white powders. One such example is Kodak White Reflectance coating No. 6080 which is available from Scientific Imaging Systems of Eastman Kodak Co., Rochester, NY. This coating is a

5 specially prepared composition of barium sulfate, binder, and solvent. Despite good initial diffuse reflectance, this material maintains its reflectance properties for only a limited period of time (e.g., for only about six months) under normal atmospheric conditions. The material is expected to be stable for even shorter periods of time when exposed to high intensity ultraviolet radiation. Furthermore, application of this coating is extremely laborious requiring 4-8 coats to ensure an adequate thickness for best reflectance. Storage, preparation, and application of the material also requires special care. Even after all of the necessary steps for application, it still does not guarantee uniform results.

10 Accordingly, there is a distinct need for a highly diffuse reflective surface that can be easily handled and installed and provide other distinct advantages over existing reflective surfaces used in luminaires.

15 SUMMARY OF THE INVENTION

The present invention relates to surfaces used to reflect light, and particularly to highly light reflectant surfaces that provide even diffusion of light for the purpose of maximizing light efficiency and/or uniformity in a luminaire.

20 The present invention employs a reflectant material of expanded polytetrafluoroethylene (PTFE) comprising polymeric nodes interconnected by fibrils defining a microporous structure. It has been determined that this structure provides extremely high diffuse reflectivity, with significantly better than the 85% reflectance of materials currently used in luminaires. Using the present invention, reflectance levels of greater than 90% and even 95% are easily achieved. In fact, the material of the present invention has demonstrated higher diffuse reflectivity than the best diffuse reflective materials presently available. This high reflectance can be exploited by either utilizing the increased luminance or by reducing the energy input necessary to maintain the same luminance. This can be accomplished by reducing the wattage or number of lamps in the luminaire. By reducing the energy input, a significant long-term cost savings can be realized.

30 Equally important, the material employed in the present invention demonstrates many other properties that make it particularly desirable for use as a reflectant material for luminaires. First, the material is highly flexible, allowing easy installation into existing planar and non-planar luminaire reflector designs. Also, the material is easily diecut, allowing a piece to be sized to the appropriate dimensions using clean and efficient methods. Furthermore, the

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material used in the present invention demonstrates superior reflectant properties even at relatively thin thicknesses such as less than 1.0 mm, 0.5 mm, 0.2 mm and even less than 0.1 mm in thickness.

5 The material of the present invention is also very stable over time with respect to a wide range of environmental conditions such as temperature extremes (-268°C to +288°C). This property enables the reflective material of the present invention to be placed in close proximity and even in contact with high temperature light sources. The material of the present invention is chemically inert, withstanding most manufacturing and end use corrosive
10 chemical environments ranging from 0-14 pH. Furthermore, the material of the present invention resists change or degradation due to exposure to ultraviolet radiation, making it ideally suitable for virtually any indoor or outdoor applications.

An additional advantage of the present invention is that the base
15 material, expanded PTFE (ePTFE), can provide an excellent gasket suitable for luminaires. Thus a one piece reflector and gasket can be provided. Furthermore, ePTFE has a very low dielectric property, which makes it a superior electrical insulation material. New lamp designs can take advantage of this reflective material to also insulate wiring from the metal parts of the
20 luminaire.

DESCRIPTION OF THE DRAWINGS

25 The operation of the present invention should become apparent from the following description when considered in conjunction with the accompanying drawings, in which:

Figure 1A is a three-quarter perspective view of a COBRA-type luminaire incorporating the present invention;

30 Figure 1B is a side elevation view of a COBRA-type luminaire incorporating the present invention;

Figure 2 is a scanning electron micrograph (SEM), enlarged 5000 times, showing the surface of a light reflectant material of a commercially available diffuse reflective material;

35 Figure 3 is a SEM, enlarged 5000 times, showing the surface of one embodiment of a light reflectant material of the present invention;

Figure 4 is a SEM, enlarged 5000 times, showing the surface of another embodiment of a light reflectant material of the present invention;

Figure 5 is a three-quarter isometric view of a reflectant material of the present invention, wherein the flexibility of the material is demonstrated:

Figure 6 is a graph plotting the reflectance verses wavelength of a reflectant material of the present invention as compared to commercially available materials:

Figure 7 is a graph plotting the reflectance verses wavelength of varying thicknesses of the reflectant material of the present invention as compared to commercially available materials:

Figure 8 is a graph plotting the reflectance verses wavelength of various structures of embodiments of the reflectant materials of the present invention:

Figure 9 is a graph plotting the reflectance verses wavelength of various thicknesses of the inventive material compared to other luminaire reflective materials:

Figure 10 is a side cross-section view of a fluorescent light fixture (luminaire) used to test the effectiveness of the present invention:

Figure 11 is bottom plan view of a light permeable cover employing louvers:

Figure 12 is a three-quarter isometric view of a fluorescent light fixture employing a light permeable cover in the form of a lens:

Figure 13 is a three-quarter isometric view of a fluorescent light fixture employing a light permeable cover in the form of a diffuser sheet:

Figure 14 is a graph plotting the data generated in the test of Example 8; and

Figure 15 is a graph plotting the data generated in the test of Example 9.

DETAILED DESCRIPTION OF THE INVENTION

The present invention generally relates to the field of lighting, and more particularly to luminaires which utilize a reflector for redirecting light. Luminaire is meant to describe a complete lighting unit consisting of a lamp or lamps together with components designed to redirect and distribute light from the lamp(s), along with a housing which positions and protects the lamps and components.

As the term "light" is used herein, it is intended to include any form of electromagnetic radiation, but especially that in the spectrum of visible light (400 to 700 nm wavelength) and through infrared (IR) light radiation (700 to greater than 2500 nm wavelength). For the present invention involving luminaires, the visible wavelengths are of the primary importance. It should be appreciated that the material of the present invention may be tailored to modify

reflectance in particular bands of light energy through the use of coatings, fillers, or similar materials.

5 A typical luminaire 2, in this case a COBRA-type street lamp luminaire, is illustrated in Figures 1A and 1B. The luminaire 2 comprises a housing 4 and one or more light sources 6. A reflector 8 is normally provided to direct light in the desired direction. Often a shield, lens or other light permeable cover 9 is also provided to better shield the light source and/or to provide particular characteristics to the light exiting the housing. As is explained below, the heart of the present invention is the reflector 8 material. This material has numerous exceptional properties, as well as being as reflective or more reflective than
10 any light reflective material available before the present invention.

Prior to the present invention, the best diffuse reflectant material commercially available was sold under the trademark SPECTRALON by Labsphere, Inc., of North Sutton, NH. This material comprises a granular
15 polytetrafluoroethylene material that is lightly packed and then molded into a rigid block. Figure 2 is a scanning electron micrograph (SEM) of a surface of a 1/2 inch (12.7 mm) thick reflectant sheet of SPECTRALON material. While this material provides good reflectivity of visible and near IR light, providing up to about 99% diffuse, "lambertian," reflectance over portions of that spectrum of light, the material has a number of drawbacks that constrain its use. Among
20 the perceived problems with this material are: difficulty in processing due to its rigidity, especially where non-planar reflectant surfaces are required; limited range of effective light reflectance across visible and IR light spectrum; relatively thick minimum thicknesses (i.e., its effective reflectance diminishes at thicknesses of less than about 4 mm); and less than optimum diffuse
25 reflectivity. Despite these deficiencies, this material is considered the present standard by which the diffuse reflectivity of all other materials is measured.

The present invention employs a distinctly different material comprising an expanded polytetrafluoroethylene (PTFE), such as that made in accordance
30 with United States Patents 3,953,566, 3,962,153, 4,096,227, 4,187,390, and 4,902,423, all incorporated by reference. This expanded PTFE material comprises a microporous structure of microscopic polymeric fibrils (i.e., thread-like elements) interconnecting polymeric nodes (i.e., particles from which fibrils emerge). The structure of a biaxially expanded example of this material is shown in the SEM of Figure 3. This material 10 comprises polymeric nodes 12
35 and numerous fibrils 14 extending from the nodes 12. As can be seen, numerous microporous voids 16 are provided within the material 10. As the term "expanded PTFE" is used herein, it is intended to include any PTFE

material having a node and fibril structure, including in the range from a slightly expanded structure having fibrils extending from relatively large nodes of polymeric or other material, to an extremely expanded structure having fibrils merely intersect with one another at nodal points.

5 Expanded PTFE has a number of important properties that make it particularly suitable as a reflectant surface of the present invention. First, PTFE is a highly inert material that is hydrophobic. Accordingly, the material is resistant to both water and a wide variety of other materials that could damage some other reflectant surfaces. Additionally, by expanding PTFE in the manner
10 taught by United States Patent 3,953,566 to form the node and fibril structure, the material undergoes a significant increase in tensile strength and becomes highly flexible. Moreover, while packed granular based PTFE material provides good diffuse reflectant properties, it has been discovered that the node and fibril structure of expanded PTFE provides a much higher diffuse reflectance
15 property.

A preferred reflectant material of the present invention is made in the following manner. A fine powder PTFE resin is blended with a lubricant, such as odorless mineral spirits, until a compound is formed. The volume of lubricant used should be sufficient to lubricate primary particles of the PTFE
20 resin so as to minimize the potential of the shearing of the particles prior to extruding.

The compound is then compressed into a billet and extruded, such as through a ram type extruder, to form a coherent sheet of extrudate. A reduction ratio of about 30:1 to 300:1 may be used (i.e., reduction ratio = cross-sectional area of extrusion cylinder divided by the cross-sectional area of the
25 extrusion die). For most applications a reduction ratio of 75:1 to 100:1 is preferred.

The lubricant may then be removed, such as through volatilization, and the dry coherent extrudate sheet is expanded rapidly in at least one direction
30 about 1.1 to 50 times its original length (with about 1.5 to 2.5 times being preferred). Expansion may be accomplished by passing the dry coherent extrudate over a series of rotating heated rollers or heated plates at a temperature of between about 100 and 325°C, such as through the method taught in United States Patent 3,953,566. Alternatively, the extruded sheet
35 may be expanded in the manner described in United States Patent 4,902,423 to Bacino, prior to removal of the lubricant.

In either case, the material may be further expanded at a ratio of 1:1 to 50:1 (with 5:1 to 35:1 being preferred) to form a final microporous sheet.

Preferably the sheet is biaxially or multi-axially expanded so as to increase its strength in both its longitudinal and transverse directions. Finally, the material may be subjected to an amorphous locking step by exposing it to a temperature in excess of 340°C.

5 The material of the present invention is preferably made in the form of sheets, which, due to their inherent flexibility may be formed into a wide variety of other shapes as desired, such as tubes, strips, convex or concave structures, etc. Additionally, to address particular applications, the material of the present invention may likewise be extruded or otherwise formed into
10 continuous tubes, rods (i.e., cylinders), rectangles, uneven shapes and other structures that may be of interest.

 Sheets made from the above processing steps can be produced in thicknesses ranging from, but not limited to, 0.01 mm to 12 mm. Sheets can be subsequently layered upon themselves and subjected to temperatures
15 ranging from about 300°C to 400°C while applying sufficient pressures to bond the layers together.

 It has been determined that by providing a microporous surface of polymeric nodes and fibrils, such as that of expanded PTFE, and particularly one that has been expanded in more than one direction, light is reflected off the
20 node and fibril structure at a very high efficiency rate, with very even diffuse dispersion (i.e., diffusion) of the light. The SEM of Figure 3 shows expanded PTFE material 10 that has undergone extensive expansion in two different directions. This structure exhibits a relatively "fine" structure with fibrils 14 oriented in both x and y directions, and small nodes 12 where the fibrils
25 intersect. Still another embodiment of the present invention is shown in the SEM of Figure 4. In this case, the expanded PTFE has been expanded in only the longitudinal direction. In this example there is a "coarser" structure characterized by larger nodes 12 and thicker fibrils 14. The fibrils 14 are oriented predominantly in a longitudinal direction.

30 As is explained in greater detail below, the present invention demonstrates extremely high diffuse reflectivity. When compared to the present reflectant standard of SPECTRALON material, the reflectant material of the present invention exhibited substantially higher diffuse reflectivity. Moreover, the reflectivity of the material of the present invention proved to have
35 a number of other dramatically improved properties over the present standard. First, the reflectivity of the material remains high across a much wider spectrum of light wavelengths. Second, the material of the present invention demonstrates exceptional reflectivity even at much thinner profiles as

compared with the existing standard material. Third, the material exhibits a very predictable, flat-line reflective response across a wide spectrum of light.

Another important improvement of the present invention is shown in Figure 5. The reflectant material 10 of the present invention is highly malleable, moldable, and flexible, allowing it to be bent, twisted, curved, or otherwise formed into any suitable shape. In this respect, the reflectant material of the present invention is a dramatic improvement over previously available highly reflectant materials, such as SPECTRALON polytetrafluoroethylene reflectant materials that must be carved or machined into desired shapes. With the material of the present invention, a host of different non-planar shapes can be formed with minimal effort. These types of thin, flexible, formable materials having at least 95%, 90%, and even 85% reflectivity should have great value for a range of luminaires. The luminance output is dependent on many factors such as lamp wattage, number of lamps, luminaire design, etc., and careful consideration can be given to determine the level of reflectance required by the reflector.

It should also be noted that the material of the present invention may be modified through processing or additional fillers and/or coatings to provide high reflectance in one range of the light spectrum and absorbance in another range of the spectrum. For most luminaire applications it is believed desirable to provide a material with a reflectivity of at least 85% over a range of 400 to 700 nm.

The present invention may comprise single or multiple layers of expanded PTFE, or may comprise a laminate of one or more layers of expanded PTFE and a backing support material. Since the expanded PTFE membrane alone tends to be susceptible to stretching and distortion, for some applications it may be preferred that the membrane be mounted to a support layer, such as through lamination to a flexible woven or non-woven material, that will help maintain the shape of the image layer during use. One suitable support layer is applied by applying an adhesive material, such as moisture curable polyurethane or solvated polyurethane, to the expanded PTFE membrane and then applying the adhesive-coated expanded PTFE membrane to a flexible backing material (e.g., polyester, polypropylene, MYLAR®, KEVLAR®, nylon, etc.). The two materials can then be bonded to each other under applied pressure, such as by rolling the material between one or more pairs of nip rollers. With use of a moisture curable polyurethane adhesive to bond an expanded PTFE membrane to a woven fabric, such as nylon. The application of a pressure of about 1150 g per linear meter is sufficient to bond

the materials together. The materials are then allowed to moisture cure for a period of about 48 hours before use.

In addition, to create complex shapes, an expanded PTFE sheet can be bonded to a rigid support material and then formed as a composite into shapes, such as parabolic or ellipsoidal domes. One suitable method for such forming techniques comprises using vacuum forming devices.

Without intending to limit the scope of the present invention, the following examples illustrate how the present invention may be made and used.

EXAMPLE 1

A reflectant material of the present invention was prepared in the following manner:

A fine powder PTFE resin was combined in a blender with odorless mineral spirits (ISOPAR K available from Exxon Corp.) until a compound was obtained. The volume of mineral spirits used per gram of fine powder PTFE resin was 0.275 cc/gm. The compound was compressed into a billet and extruded through a 1.14 mm gap die attached to a ram type extruder to form a coherent extrudate. A reduction ratio of 47:1 was used.

Subsequently, the odorless mineral spirit was volatized and removed, and the dry coherent extrudate was expanded uniaxially in the longitudinal direction 4.0 times its original length by passing the dry coherent extrudate over a series of rotating heated rollers at a temperature of 300°C. The sheet was subsequently subjected to an amorphous locking step by passing the sheet over a series of rotating heated rollers at a temperature of 385°C such that the material was in contact with the rollers for about 12 seconds.

This material formed a relatively coarse expanded structure such as that shown in Figure 4.

EXAMPLE 2

Another sheet of the present invention was produced in the same manner as Example 1 except for the following differences:

The volume of mineral spirits used per gram of fine powder PTFE resin was 0.297 cc/gm. The compound was compressed into a billet and extruded through a 1.52 mm gap die attached to a ram type extruder to form a coherent extrudate. A reduction ratio of 70:1 was used.

Subsequently, the odorless mineral spirit was volatized and removed. Three layers of the dry coherent extrudate were then stacked and expanded

uniaxially in the longitudinal direction 4.6 times its original length by passing the dry coherent extrudate over a series of rotating heated rollers at a temperature of 310°C. The sheet was subsequently subjected to an amorphous locking step by passing the sheet over a series of rotating heated rollers at a temperature of 385°C for about 40 seconds.

Again, this material formed a relatively coarse expanded structure such as that shown in Figure 4.

EXAMPLE 3

A sheet of the present invention was produced in the following manner.

A fine powder PTFE resin was combined with an odorless mineral spirit. The volume of mineral spirits used per gram of fine powder PTFE resin was 0.275 cc/gm. This mixture is aged below room temperature to allow for the mineral spirits to become uniformly distributed within the PTFE fine powder resin. This mixture was compressed into a billet and extruded at approximately 8300 kPa through a 0.71 mm gap die attached to a ram type extruder to form a coherent extrudate. A reduction ratio of 75:1 was used.

The extrudate is then rolled down between two metal rolls which were heated to between 30-40°C. The final thickness after roll down was 0.20 mm. The material was transversely expanded at a ratio of 3:1 and then the mineral spirits were removed from the extrudate by heating the mass to 240°C (i.e., a temperature where the mineral spirits were highly volatile). The dried extrudate was transversely expanded at 150°C at a ratio of 3.5:1. After expansion, the sheet was amorphously locked at greater than 340°C and cooled to room temperature. This material forms a relatively fine expanded structure such as that shown in Figure 3.

Multiple layers of this sheet material can then be stacked, placed under pressure, and exposed to a temperature of about 360°C for about 30 minutes to bond the layers into a cohesive sheet of virtually any desired thickness.

EXAMPLE 4

Layered expanded PTFE material similar to that described in Example 3 above is commercially available from W. L. Gore & Associates, Inc., Elkton, MD, as a sheet gasket material under the trademark GORE-TEX GR® sheet gasketing. This material is available in different thicknesses (i.e., constituting different number of layers formed into cohesive sheets). In order to test the effectiveness of the material of the present invention as compared to

commercially available light reflectant materials. various samples of sheet gasketing material were tested as follows.

5 Sample 1 A composite sheet comprising about 15 layers of expanded PTFE sheets with the following properties.

Thickness:	0.5 mm
Density:	0.60 g /cc

10 Sample 2: A composite sheet comprising about 25 layers of expanded PTFE sheets with the following properties:

Thickness:	1.0 mm
Density:	0.57 g /cc

15 Sample 3: A composite sheet comprising about 60 layers of expanded PTFE sheets with the following properties:

Thickness:	2.2 mm
Density:	0.61 g /cc

20 Sample 4: A composite sheet comprising about 85 layers of expanded PTFE sheets with the following properties:

Thickness:	3.4 mm
Density:	0.59 g /cc

25 Sample 5: A composite sheet comprising about 150 layers of expanded PTFE sheets with the following properties:

Thickness:	6.2 mm
Density:	0.51 g /cc

30 Additionally, material similar to that described in Examples 1 and 2. above, is commercially available from W. L. Gore & Associates, Inc., as a gasket tape under the trademark GORE-TEX® gasket tape. Again, this material is available in different thicknesses. Samples of this material were tested as follows:

35 Sample 6: A gasket tape comprising a single layer of relatively coarse expanded PTFE with the following properties:

Thickness:	1.0 mm
Density:	0.50 g /cc

Sample 7: A gasket tape comprising a single layer of relatively coarse expanded PTFE with the following properties

	Thickness:	3.3 mm
5	Density:	0.66 g /cc

Each of Samples 1 through 7 were tested in the following manner to quantify their reflective properties:

10 A 2 inch by 2 inch (51 mm x 51 mm) swatch from each of Samples 1 through 7 was placed in a CARY 5E Spectrophotometer with a Labsphere integrating sphere. The spectral range measured was 175 nm to 2500 nm. Data below 250 nm was not reported due to the unreliability of the standard material below this value. All measurements were made in the double-beam mode with the same working standard in the sphere's reference reflectance
15 port. The reflectance standard used was of SPECTRALON material. Labsphere Serial Number SRS-99-010-8111-A. Photomultiplier detection was used below 800 nm and lead sulfide detection was used above 800 nm. All measurements were normalized with respect to the baseline of the system. This data is then corrected by multiplying it by the correction factors supplied
20 with the reflectance standard. This data was then averaged and plotted.

The graph of Figure 6 records the reflectance verses light wavelength of one sample of the present invention as compared with three commercially available reflectant materials. Line 18 is the performance of the material of Sample 5 of the present invention as compared with commercially available
25 reflectant materials SPECTRALON (Line 20), SPECTRAFLECT (Line 22), and INFRAGOLD (Line 24), each available from Labsphere, Inc., North Sutton, NH. These materials are represented by their manufacturer to be some of the highest diffuse reflectant materials available. The data plotted for the commercially available materials was obtained from the technical information
30 catalog published by Labsphere, Inc. As can be seen, at all wavelengths of light tested, the reflectant material of the present invention demonstrated markedly higher reflectivity than the commercially available reflectant materials. Additionally, the material of the present invention retained its reflective properties into much higher wavelengths than the commercial materials.

35 It should be noted here that the reflectivity numbers reported herein are not asserted to show better than complete reflectance of light, but, rather, as demonstrating significantly better reflectance than the present state-of-the-art SPECTRALON reflectant material used as a standard.

The graph of Figure 7 records the reflectance verses light wavelength of different thicknesses of inventive material compared to similar thicknesses of SPECTRALON reflective material. Lines 26, 28, 30, and 32 respectively represent the performance of Samples 1, 2, 3, and 4 of the present invention. By way of comparison, lines 34, 36, and 38 respectively represent the performance of 1.0 mm, 2.0 mm, and 3.0 mm thick samples of SPECTRALON material according to published data from the technical catalog of Labsphere, Inc. Sample 1 was included here even though information is not available for SPECTRALON material at a thickness of 0.5 mm. In all cases the inventive material was substantially higher in reflectivity than SPECTRALON reflectant material of similar thickness. This difference appears to be even more pronounced as the materials decrease in thickness. It should be noted that the 0.5 mm material of the present invention, even though six times thinner than the 3.0 mm SPECTRALON material, demonstrates equal to or higher reflectivity within the visible wavelengths of 400 to 700 nanometers.

The graph of Figure 8 records the reflectance verses light wavelength of four samples with similar densities of expanded PTFE material of the present invention. Of the four samples, there are two different thickness levels represented, with a coarse and fine structure material at each level. Lines 40 and 42 represent Samples 6 and 7, respectively, each with a relatively coarse structure characterized by large nodes and thick fibrils. Lines 44 and 46 represent Samples 2 and 4, respectively, each having a relatively fine structure characterized by small nodes and fine fibrils.

In like thickness comparisons, the finer structure material demonstrated much higher reflectivity than the coarser structure material at all wavelengths tested. For instance, Sample 2 with a thickness of 1.0 mm was substantially more reflective than Sample 6 with the same thickness of 1.0 mm.

EXAMPLE 5

Another layered expanded PTFE material similar to that described in Example 4 was produced:

A composite sheet comprising about 7 layers of expanded PTFE sheets with the following properties:

Thickness:	0.22 mm
Density:	0.60 g /cc

EXAMPLE 6

Another layered expanded PTFE material similar to that described in Example 4 was produced:

- 5 A composite sheet comprising about 3 layers of expanded PTFE sheets with the following properties:

Thickness:	0.11 mm
Density:	0.60 g /cc

10 **EXAMPLE 7**

Another layered expanded PTFE material similar to that described in Example 4 was produced:

- 15 A composite sheet comprising about 2 layers of expanded PTFE sheets with the following properties:

Thickness:	0.07 mm
Density:	0.60 g /cc

- 20 The graph of Figure 9 records the reflectance verses light wavelength of different thicknesses of inventive material compared to typical light reflectant materials used in luminaires. Lines 47, 48, 49, and 50 respectively represent the performance of Sample 1 from Example 4 and Examples 5, 6, and 7 of the present invention. By way of comparison, lines 52, 54, and 56 respectively represent the performance of diffuse aluminum, white porcelain enamel, and
- 25 white synthetic enamel according to published data from the LIGHTING HANDBOOK, 8th edition, Illuminating Engineering Society of North America, page 324 (1993). In all cases the inventive material was substantially higher in reflectivity than all of the typical diffuse reflectant materials used in luminaires. It is also important to note that all of the materials of the present invention have
- 30 relatively flat spectral response across the visible spectrum as compared to the typical luminaire reflectant materials. A reflectant material having a flat line response reflects all wavelengths equally thus reflecting the true color of the lamp source.

35 **EXAMPLE 8**

A typical recessed fluorescent light fixture is illustrated in Figure 10. This fixture 58 comprises a troffer 60, a light permeable cover 62, a reflector 64, and multiple lights 66a, 66b, 66c, 66d. The unit shown has a 2 foot x 4 foot

(600 x 1200 mm) troffer 60 and a prismatic lens 62. This type of fixture is commercially available from Cooper Lighting of Eufaula, Alabama. The fixture utilizes four 4100K T8 32 watt fluorescent lamps and electronic ballast with a reflector of diffuse white paint on aluminum.

5

Test Method

As is illustrated in Figures 11 through 13, a number of other light permeable covers 62 may be used with this type of fixture. Figure 11 shows a cover 62 having numerous louvers 68 for directing light in particular directions. Figure 12 shows a fixture 58 having a lens cover 70. The lens is provided to improve diffusion of light exiting the fixture. Figure 13 shows a fixture 58 employing a diffuser 72. Again, the diffuser serves to provide even distribution of light exiting the fixture.

A test was conducted using the fluorescent fixture illustrated in Figure 10. The test procedure used is set forth below.

The luminance of the luminaire was measured by positioning the lamp centered and parallel to a diffuse reflective surface (screen) as recommended by the National Lighting Product Information Program, Specifier Reports, Volume 3, Number 1. The screen material chosen was a 0.5 mm thick piece of the inventive material having dimensions of 152.4 cm x 152.4 cm. The luminaire was placed 21.6 cm from the screen. A uniform grid of 15 by 15 squares was drawn on the screen yielding 225 total measurement locations. A radiometer probe was mounted on a stand so that the end of the probe was positioned 3.5 cm from the screen at a fixed 45 degrees angle from the screen. Measurements of each target (the center of each square of the grid) were recorded in Foot Lamberts. The probe used was a model number SPL 025Y connected to a model number IL1400 monitor both available from International Light Inc. of Newburyport, Mass. The luminance measurements began 30 minutes after the lamps were energized.

The reflector of the luminaire was then lined with 0.5 mm thick inventive material made in accordance with Sample 1 of Example 4. Strips of pressure sensitive adhesive were used to hold the inventive lining material in place. Measurements were then taken and recorded according to the above described test method.

In a further test using the ePTFE lined luminaire, one of the two center lamps was removed leaving three of the original four lamps. Measurements were again taken and recorded according to the above described test method.

The data from the above three tests are shown in Tables 1, 2, and 3, respectively. The columns, labeled A through O, correspond to the width of the luminaire while rows 1 through 15 correspond to the length of the luminaire. The columns from Tables 1, 2, and 3 were averaged and graphed as shown in Figure 14. Additionally, the total average luminance measurements were calculated for each test. The control had an average luminance of 478 foot lamberts. The lined four lamp luminaire had an average luminance of 604 foot lamberts, representing an increased overall luminance of 26.4%. The lined three lamp luminaire had an average luminance of 490 foot lamberts. It is important to note that even when a lamp was removed, the average luminance showed a 2.5% increase over the control.

Figure 14 represents the averaged columns from each of the three tests. It is important to note that for all column averages, both of the lined examples exceeded those of the control. Comparing the control test with the ePTFE lined four lamp test, the only difference was the addition of the ePTFE reflective liner. Between these two tests, all column averages showed a similar level percentage increase with each column having a luminance increase greater than 20%. Thus there was an overall increase in luminance of the luminaire, but there was a minimal effect on the light distribution pattern of the luminaire.

EXAMPLE 9

A test was conducted to determine luminance output of a Cobra Style Highway luminaire catalog # M2RR15S1N2AMS3099 commercially available from GE Lighting Systems of Hendersonville, NC, with a prismatic lens and 150 watt lamp. This luminaire utilized a reflector material of diffuse aluminum.

The test method from Example 8 was repeated with the Cobra luminaire being 17.8 cm from the screen. The reflector of the luminaire was then lined with 1.0 mm thick inventive material made in accordance with Sample 2 of Example 4. Strips of pressure sensitive adhesive were used to hold the inventive lining material in place. Measurements were then taken and recorded according to the above described test method.

The data from the above two tests are shown in Tables 4 and 5, respectively. The columns, labeled A through O, correspond to the width of the luminaire while rows 1 through 9 correspond to the length of the luminaire. The columns from tables 5 and 6 were averaged and graphed as shown in Figure 15. Additionally, the total average luminance measurements were calculated for each test. The control had an average luminance of 639 foot lamberts. The

ePTFE lined luminaire had an average luminance of 763 foot lamberts, representing an increased overall luminance of 19.4%.

Figure 15 represents the averaged columns from each of the two tests. It is important to note that for this application, the centermost columns experienced a large percentage increase in luminance, whereas the outermost columns did not have an increase, with some of these outermost columns showing a small decrease. Thus, there was an overall increase luminance of the luminaire, however in this example the light distribution pattern was modified to enhance the centermost region of the lighting area.

The above Examples demonstrate that the reflectant material of the present invention performs far better and more consistently as a diffuse reflectant material over a wider spectrum of light than the best diffuse reflectant materials used for luminaires.

While particular embodiments of the present invention have been illustrated and described herein, the present invention should not be limited to such illustrations and descriptions. It should be apparent that changes and modifications may be incorporated and embodied as part of the present invention within the scope of the following claims.

Table 1

CONTROL - STANDARD WHITE PAINTED ALUMINUM REFLECTOR (AS PURCHASED)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	30	45	68	107	182	229	256	284	271	231	169	112	69	43	32
2	36	56	96	189	341	494	570	566	556	476	332	183	96	58	36
3	42	75	125	271	504	773	888	858	869	753	512	278	133	72	39
4	52	87	150	343	628	974	1124	1082	1116	963	652	343	158	84	45
5	56	99	183	381	718	1107	1265	1210	1262	1100	750	392	174	94	48
6	64	106	189	423	762	1172	1355	1306	1339	1160	790	422	197	101	51
7	60	113	194	451	811	1211	1400	1340	1390	1199	820	437	208	104	48
8	60	111	188	460	835	1237	1429	1370	1405	1215	831	430	206	103	47
9	55	115	194	475	846	1228	1408	1351	1396	1206	829	417	209	101	48
10	45	103	192	432	793	1200	1378	1320	1365	1175	795	430	193	105	43
11	44	92	177	413	770	1130	1307	1260	1296	1118	750	402	186	94	48
12	39	84	157	369	687	1002	1142	1105	1141	1002	676	357	163	89	34
13	33	75	128	285	551	794	922	891	884	772	513	283	135	73	28
14	26	59	103	196	352	502	580	577	568	493	330	193	95	57	24
15	20	42	66	107	189	241	291	289	288	240	172	111	69	42	21
Column															
Avg	44	84	147	327	598	886	1021	987	1010	874	595	319	153	81	39

Total Avg. 478

Table 2

LINED WITH 0.5 MM THICK ePTFE INVENTIVE MATERIAL

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	38	52	81	124	210	270	324	350	329	282	210	136	84	52	39
2	45	66	112	216	416	623	738	719	717	620	422	231	116	71	46
3	52	87	151	317	635	985	1149	1103	1111	977	660	347	163	92	52
4	64	102	182	418	802	1244	1447	1381	1447	1260	847	438	204	109	63
5	69	115	225	472	908	1411	1627	1568	1625	1426	949	487	219	119	64
6	78	129	226	519	965	1514	1730	1660	1723	1499	1000	519	241	126	67
7	73	134	231	542	1020	1561	1780	1709	1788	1547	1038	546	259	131	69
8	76	132	228	553	1038	1575	1800	1734	1803	1559	1053	544	263	136	73
9	67	138	233	567	1032	1562	1779	1720	1773	1545	1045	522	262	131	75
10	64	130	233	529	986	1518	1735	1668	1718	1493	1000	537	243	132	60
11	56	115	222	506	935	1425	1633	1570	1618	1400	932	485	234	114	59
12	49	104	190	450	839	1246	1426	1386	1415	1232	823	444	209	105	43
13	37	89	161	353	681	988	1151	1100	1099	965	643	366	180	93	41
14	35	78	131	242	448	634	744	741	716	622	424	245	129	76	35
15	31	57	87	136	244	315	396	402	358	305	236	143	91	55	31
Column															
Avg	56	102	180	396	744	1125	1297	1254	1283	1115	752	399	193	103	54

Total Avg. 604

Table 3

LINED WITH 0.5 MM THICK ePTFE INVENTIVE MATERIAL WITH 1 OF 4 LAMPS REMOVED

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	30	41	70	115	188	247	274	283	260	227	163	107	64	42	29
2	36	57	99	204	374	556	633	589	533	450	322	172	88	54	34
3	43	77	135	305	580	874	983	874	872	734	495	263	122	68	38
4	53	91	163	394	737	1109	1227	1086	1095	936	627	326	144	77	45
5	58	103	197	442	838	1255	1394	1244	1236	1050	704	356	156	86	47
6	65	110	207	473	879	1334	1475	1314	1322	1115	748	387	175	92	49
7	60	115	211	501	927	1366	1515	1345	1358	1150	768	406	190	96	49
8	62	108	204	501	949	1387	1535	1357	1375	1160	786	401	188	98	52
9	54	112	204	512	948	1383	1521	1342	1361	1153	775	400	194	97	55
10	56	108	209	478	900	1346	1477	1284	1320	1116	746	400	177	100	47
11	59	97	195	457	863	1263	1410	1241	1243	1052	703	383	179	91	48
12	43	89	166	412	759	1111	1222	1093	1092	933	630	339	156	84	35
13	32	79	141	315	616	882	987	865	864	730	490	271	132	70	29
14	24	60	108	210	381	550	619	571	551	468	318	178	93	57	25
15	24	44	71	116	203	259	305	269	283	236	170	108	68	41	22
Column															
Avg	47	86	159	362	676	995	1105	984	984	834	563	300	142	77	40

Total Avg. 490

Table 4
CONTROL - COBRA STYLE HIGHWAY LUMINAIRE

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	45	61	67	88	93	105	127	142	152	108	104	87	68	60	37
2	65	93	125	221	263	258	300	420	359	250	260	163	110	80	53
3	82	185	233	490	1039	950	1020	1590	1210	907	940	297	207	157	90
4	93	294	658	1250	1620	1405	1850	3120	2210	1520	1306	934	617	350	90
5	75	188	455	1107	2030	2390	2760	2990	3020	2510	1830	1080	610	260	79
6	55	125	276	617	1111	1680	2750	2300	2360	1510	1060	578	342	177	50
7	43	109	246	495	1121	1660	1710	1650	1550	1370	839	453	252	108	41
8	36	73	167	282	471	461	688	840	599	360	306	206	131	68	29
9	28	47	69	90	179	343	413	413	331	237	140	82	59	44	26
58	131	255	516	881	1028	1291	1496	1310	975	754	431	266	145	55	

Table 5
 LINED WITH 1.0 MM THICK ePTFE INVENTIVE MATERIAL

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	40	56	64	90	108	122	133	143	141	128	109	91	68	56	33
2	52	76	92	172	237	315	332	369	329	270	253	147	107	77	42
3	57	117	147	274	450	730	982	1057	960	716	494	233	173	119	70
4	65	156	356	604	850	1360	1660	1910	1630	1240	779	507	336	224	79
5	73	155	332	730	1560	2770	3780	3400	3240	2650	1398	698	419	223	87
6	76	146	335	815	1650	2980	4720	4470	3930	2820	1530	762	438	272	79
7	57	139	314	680	1550	2630	3230	3410	2980	2500	1370	729	400	230	56
8	42	100	202	340	600	868	1440	1840	1345	817	562	350	220	149	41
9	49	70	97	141	309	585	769	890	690	485	272	153	100	74	35
Column															
Avg	57	113	215	427	813	1373	1894	1943	1694	1292	752	408	251	158	58

Total Avg. 763

The invention claimed is:

- 1 1. A method of providing improved diffuse reflectivity of light in a
2 luminaire comprising
3 providing a reflectant material comprising an expanded
4 polytetrafluoroethylene having polymeric nodes interconnected by fibrils
5 defining microporous voids therein; and
6 mounting the reflectant material in a luminaire so as to cause
7 light energy to reflect off it.
- 1 2. The method of claim 1 that further comprises providing as the
2 reflectant material a material with a diffuse reflectance of greater than 85% of
3 the light striking the reflectant material reflecting from the material.
- 1 3. The method of claim 1 that further comprises providing as the
2 reflectant material a material with a diffuse reflectance of greater than 90% of
3 the light striking the reflectant material reflecting from the material.
- 1 4 The method of claim 1 that further comprises providing as the
2 reflectant material a material with a diffuse reflectance of greater than 95% of
3 the light striking the reflectant material reflecting from the material.
- 1 5. The method of claim 1 that further comprises
2 providing as the reflectant material a flexible sheet of expanded
3 polytetrafluoroethylene, allowing the reflectant material to be readily formed
4 into different shapes; and
5 forming the reflective material to provide a non-planar reflective
6 surface.
- 1 6. A luminaire comprising
2 at least one sheet of expanded polytetrafluoroethylene (PTFE)
3 comprising a structure of nodes and fibrils, the sheet being conformable;
4 at least one light source mounted in the luminaire;
5 the sheet of expanded PTFE being mounted in the luminaire so
6 as to provide a high diffuse reflectance of light from the luminaire.
- 1 7. The luminaire of claim 6 which further comprises;
2 a means to redirect the light exiting the luminaire.
- 1 8. The luminaire of claim 7 where the means to redirect the light exiting
2 the luminaire is a diffuser.
- 1 9. The luminaire of claim 7 where the means to redirect the light exiting
2 the luminaire is a lens.
- 1 10. The luminaire of claim 7 where the means to redirect the light
2 exiting the luminaire is a louver.

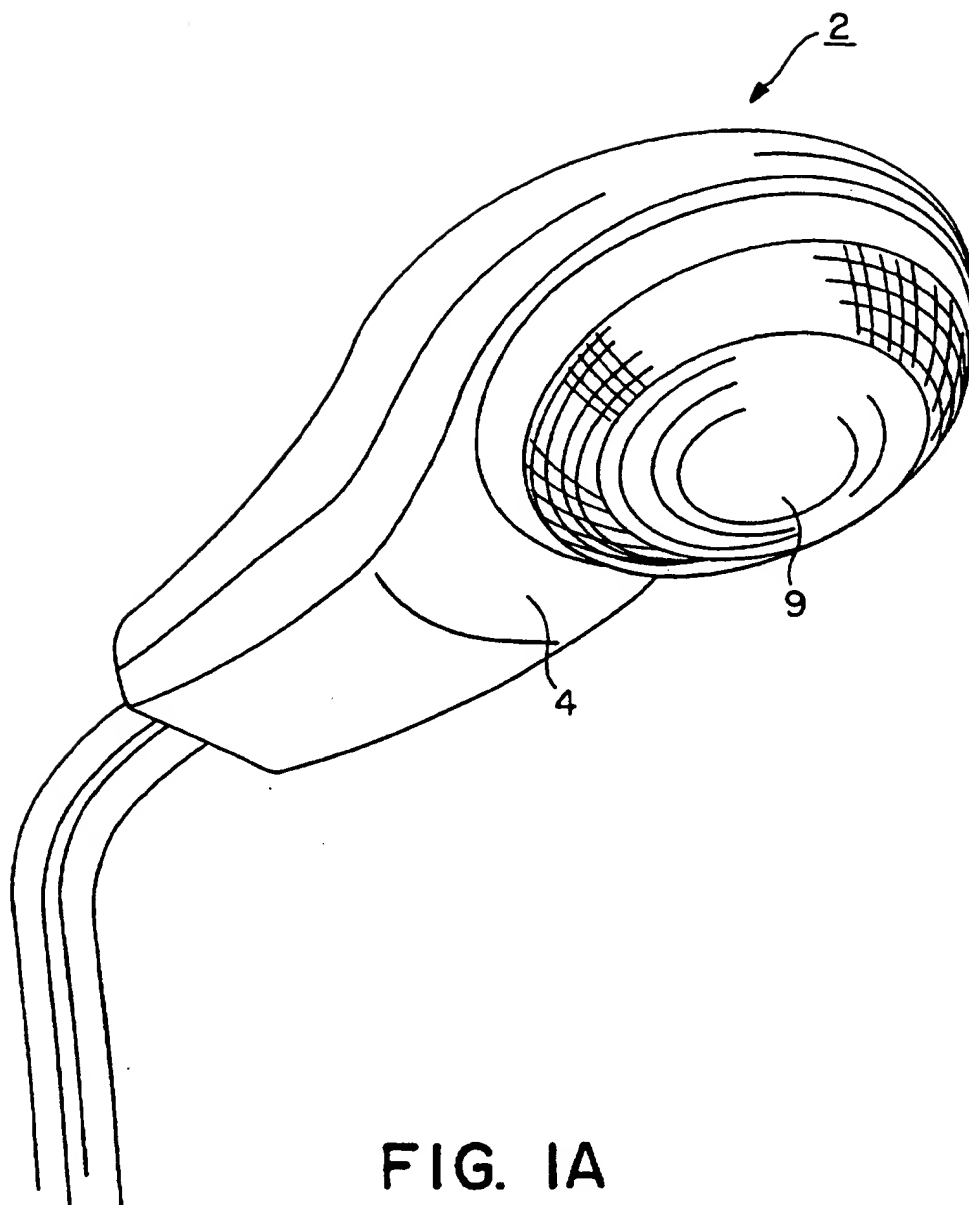


FIG. 1A

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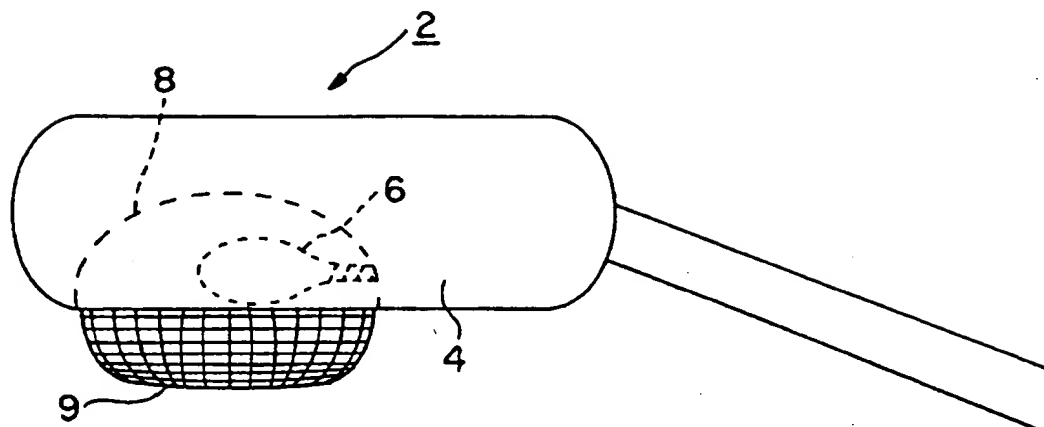


FIG. 1B

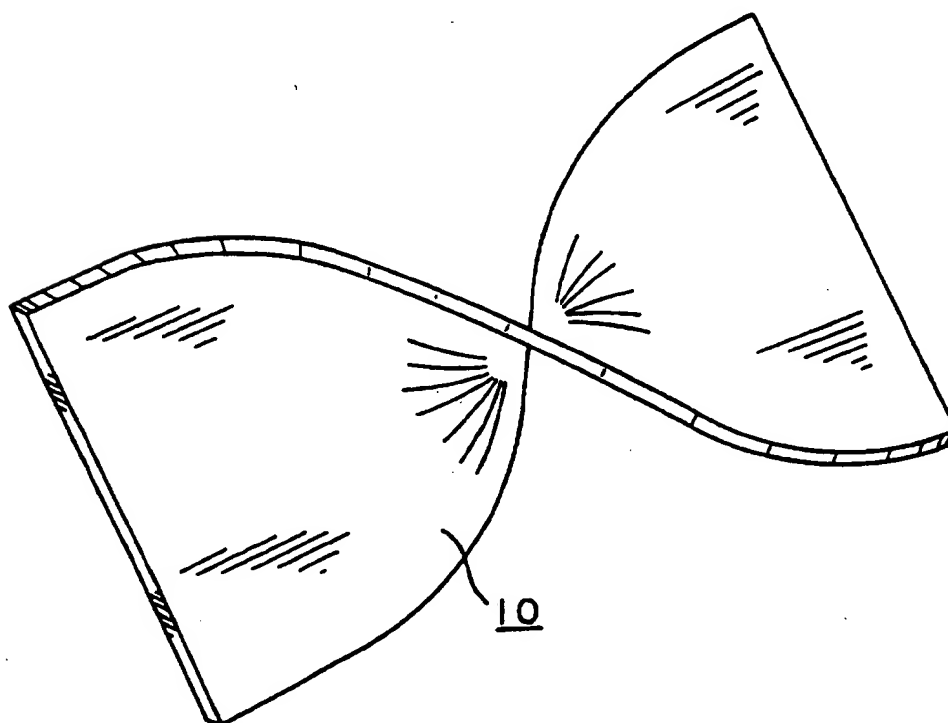


FIG. 5

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FIG. 2

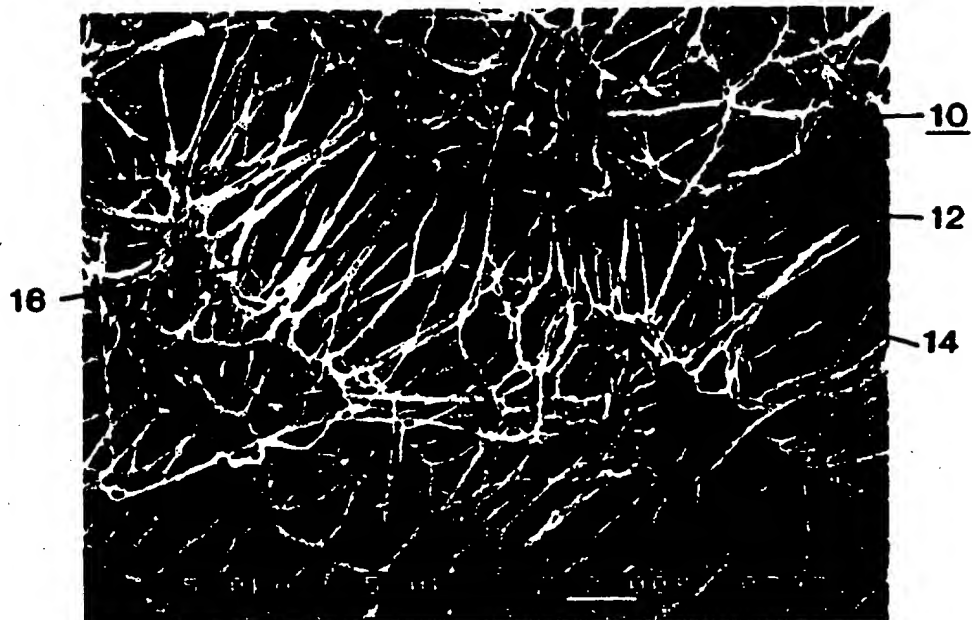


FIG. 3

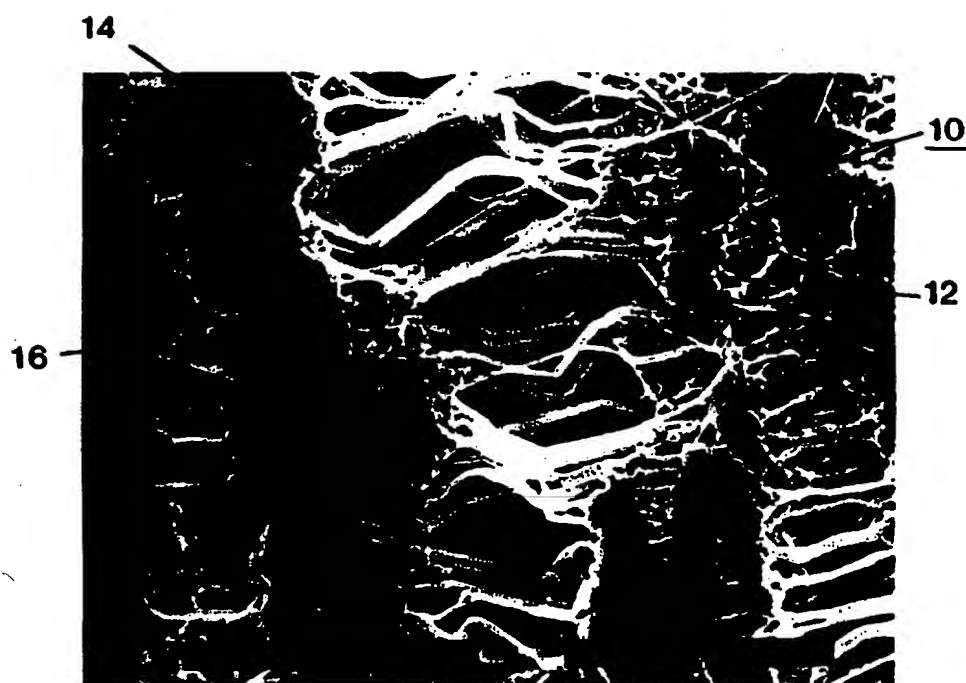
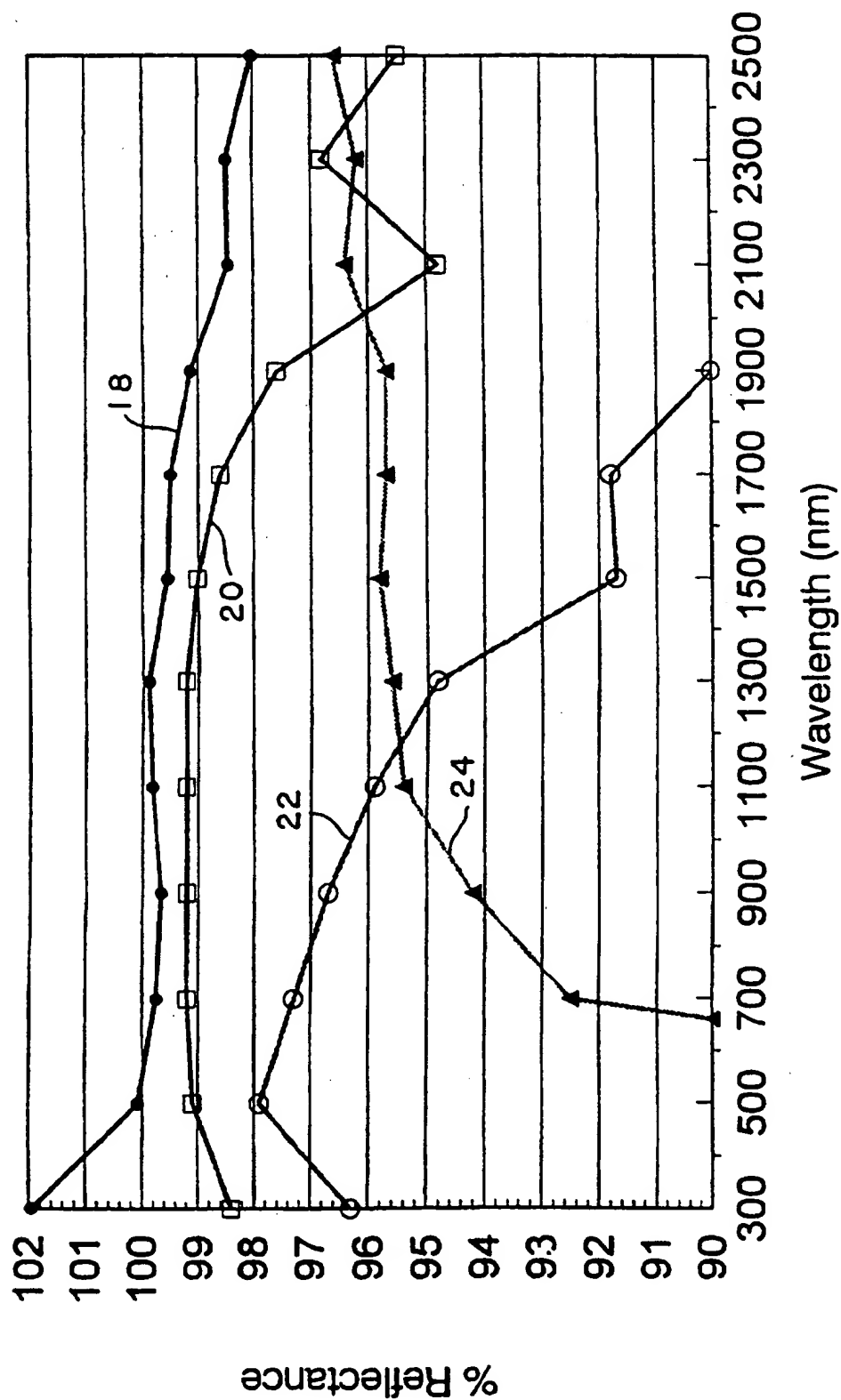


FIG. 4



Wavelength (nm)

FIG. 6

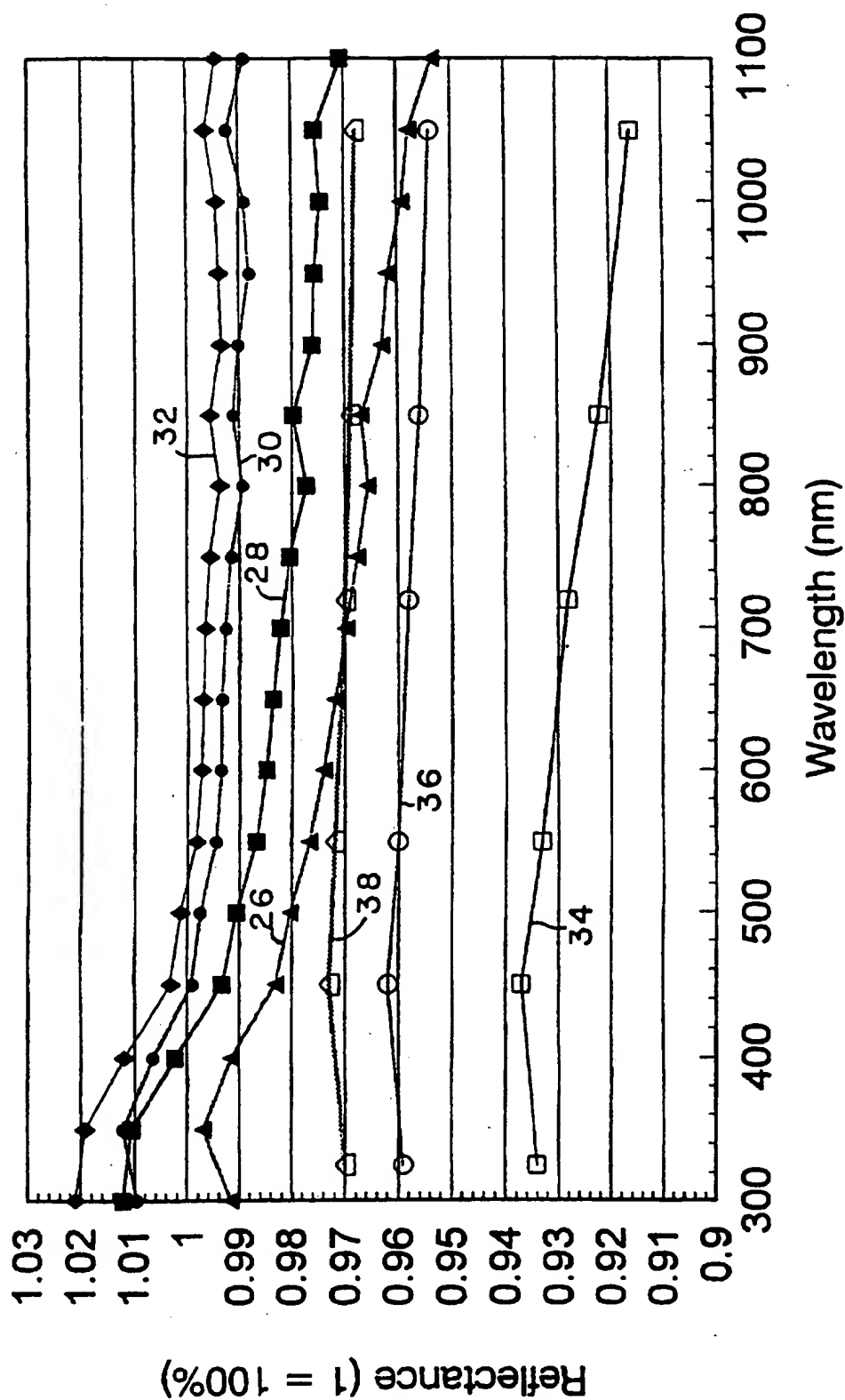
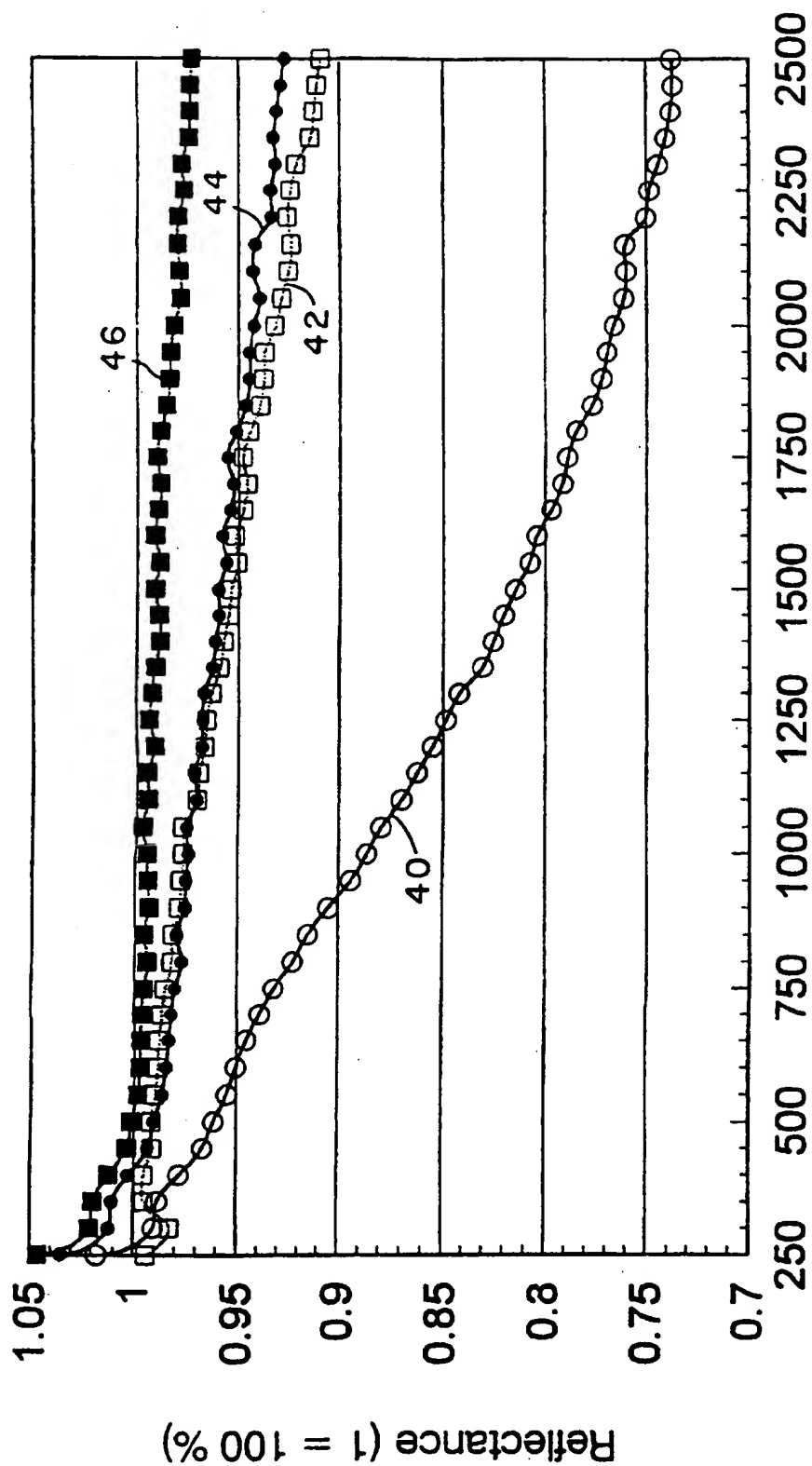
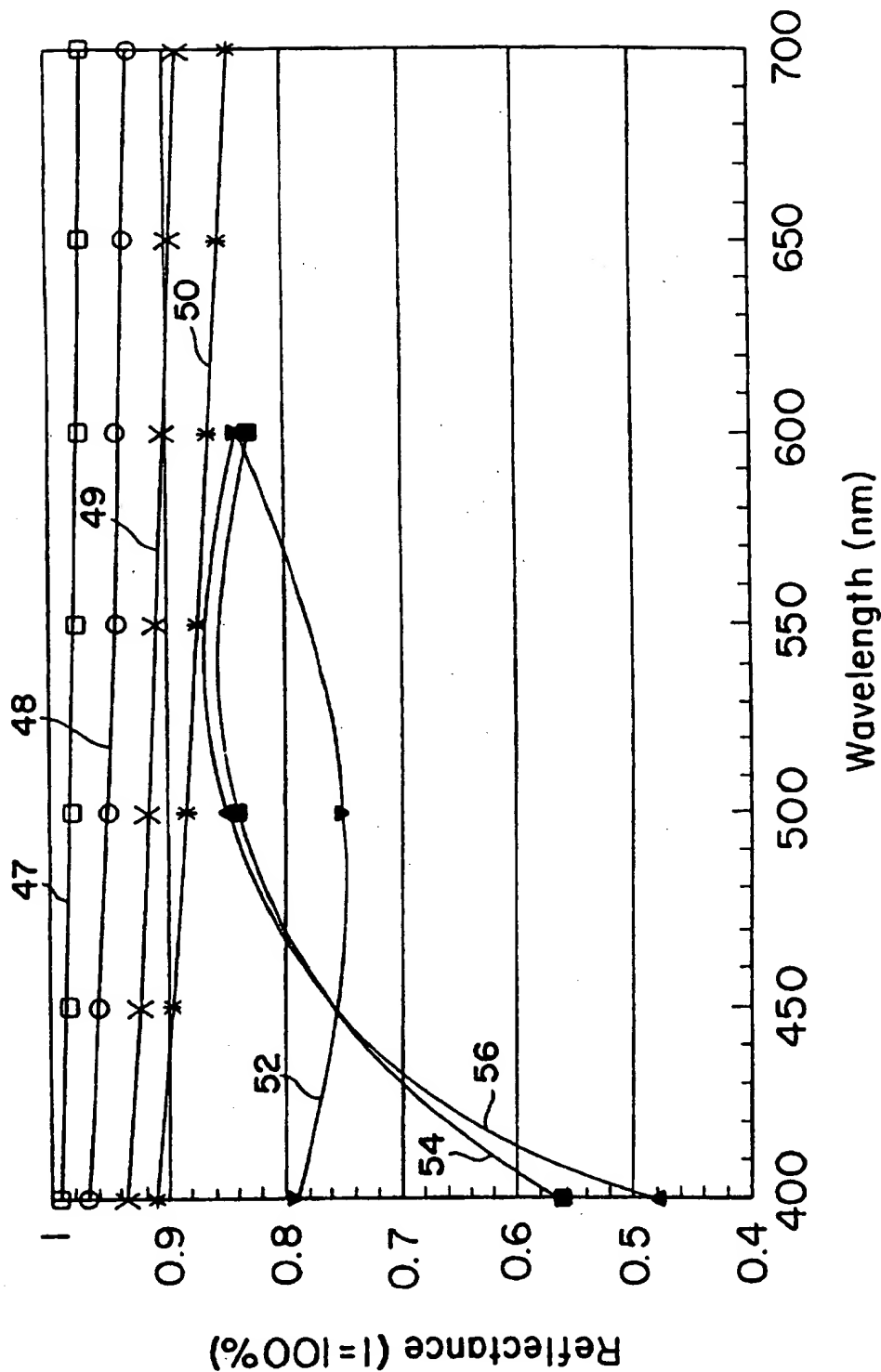


FIG. 7



Wavelength (nm)

FIG. 8



Wavelength (nm)

FIG. 9

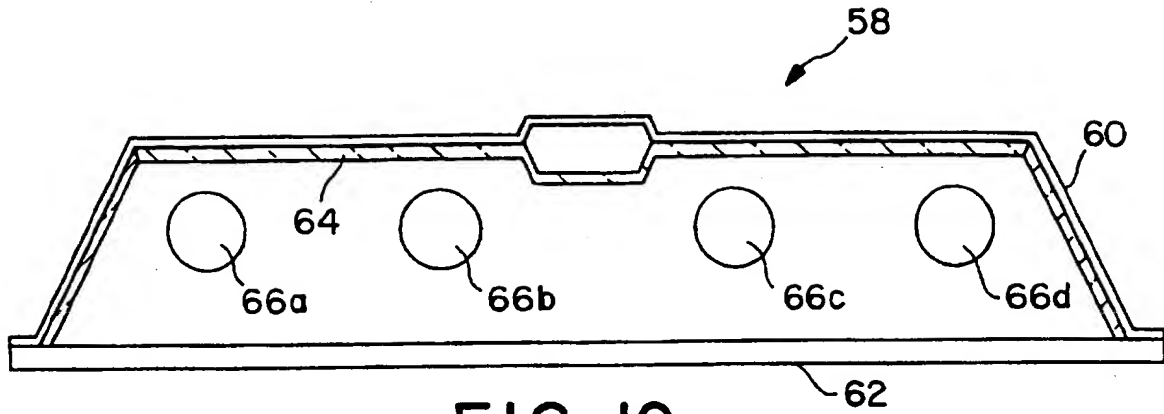


FIG. 10

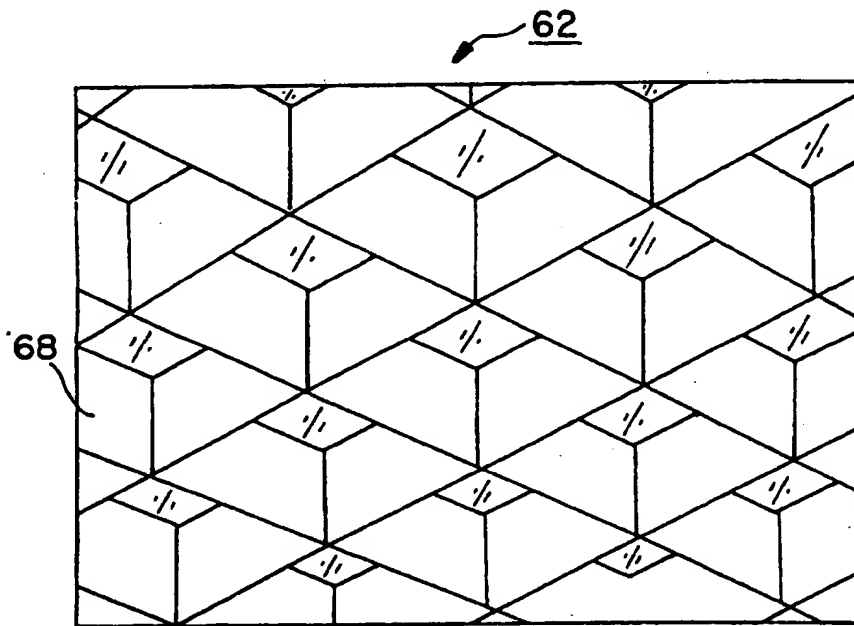
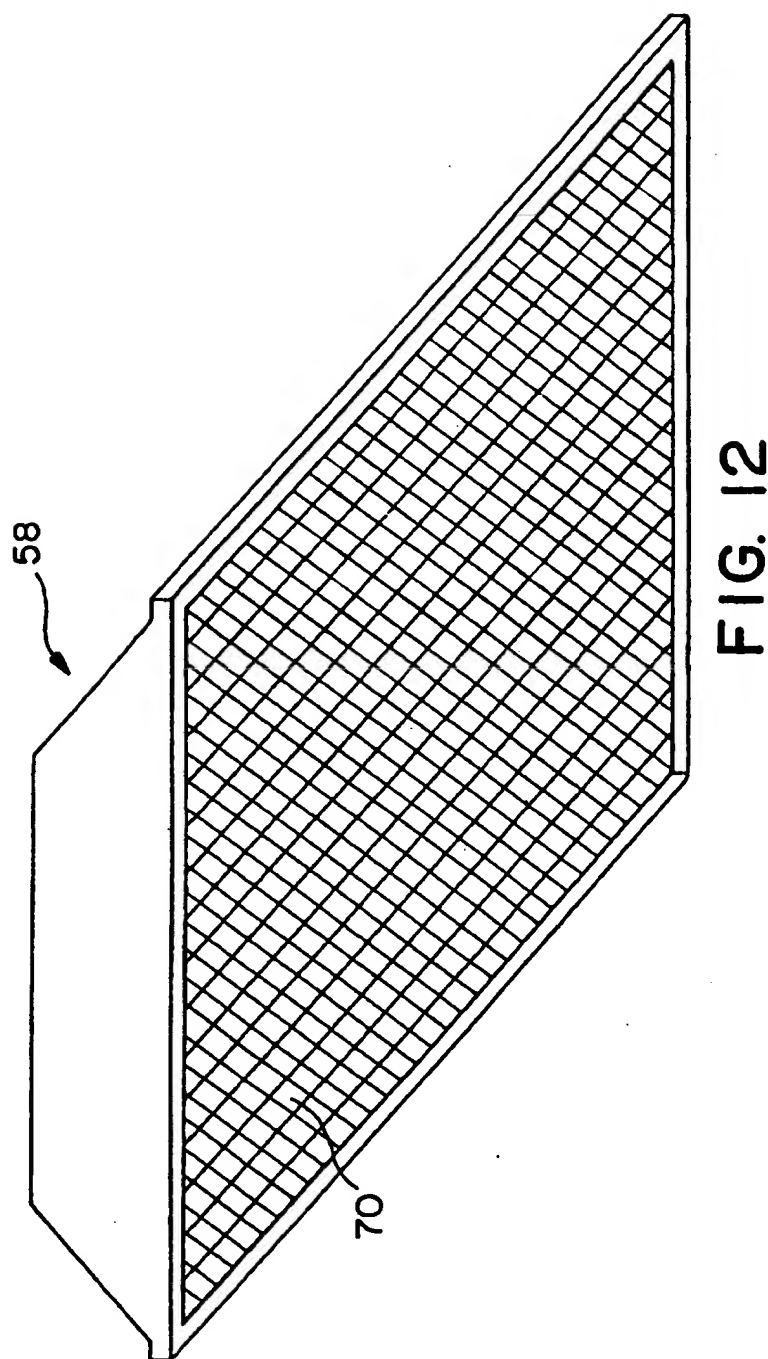


FIG. 11



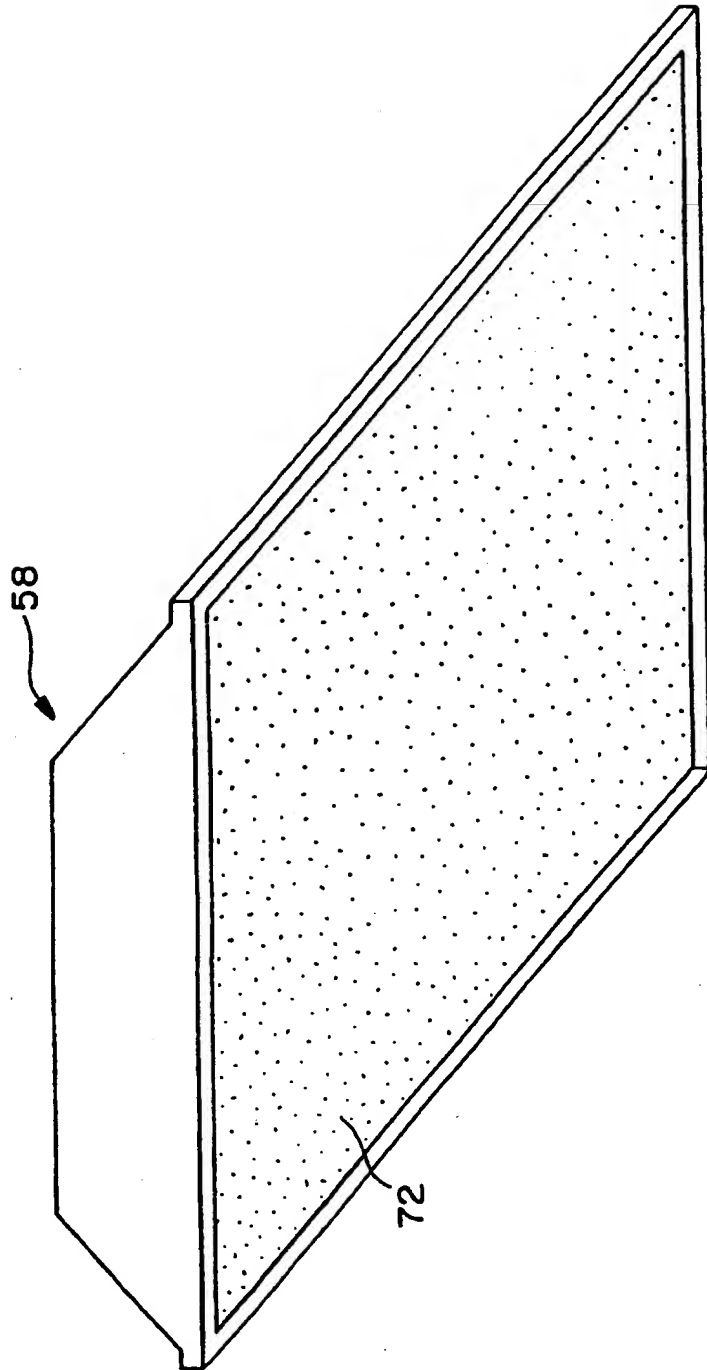


FIG. 13

12 / 13

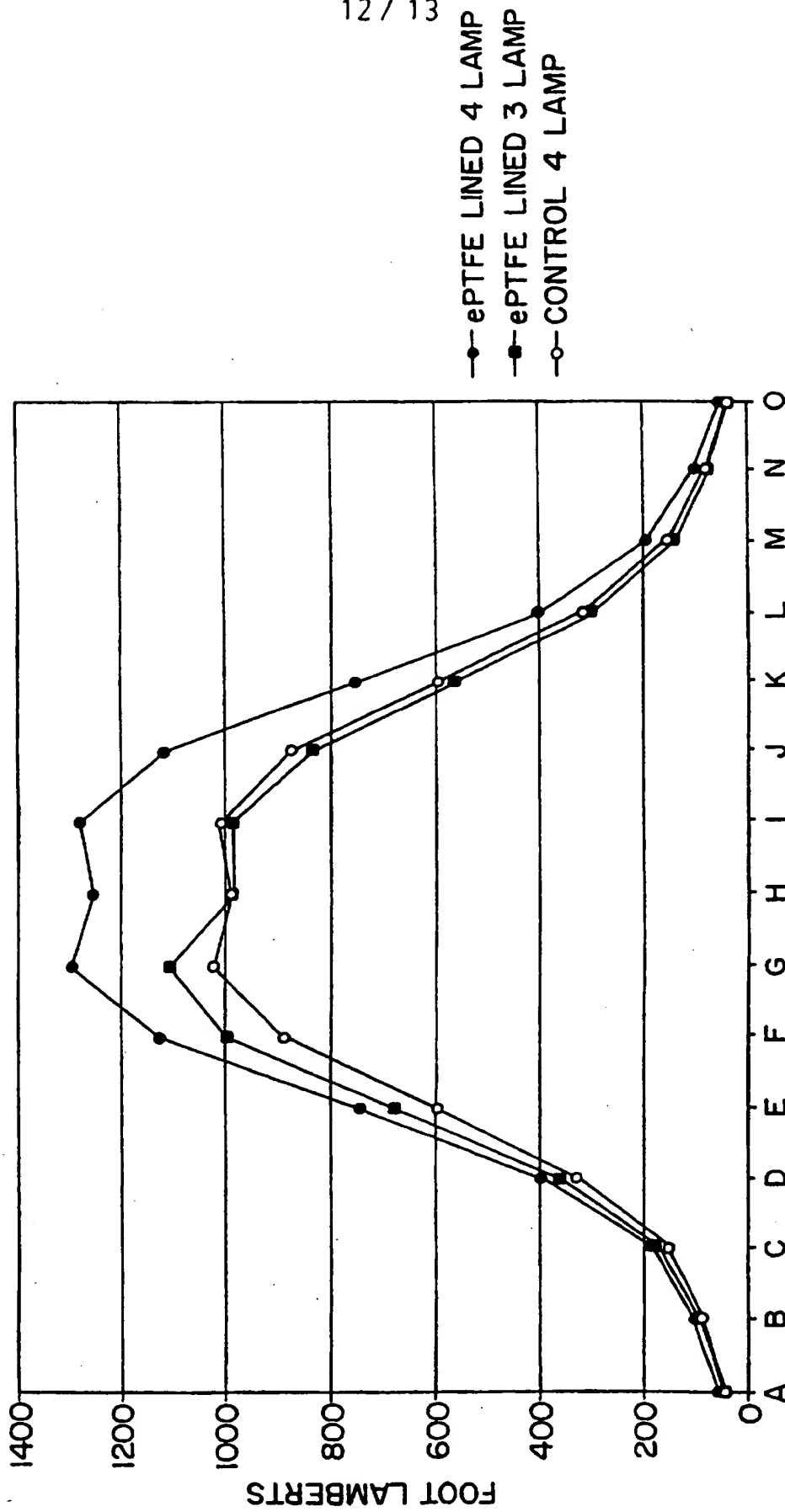


FIG. 14

13 / 13

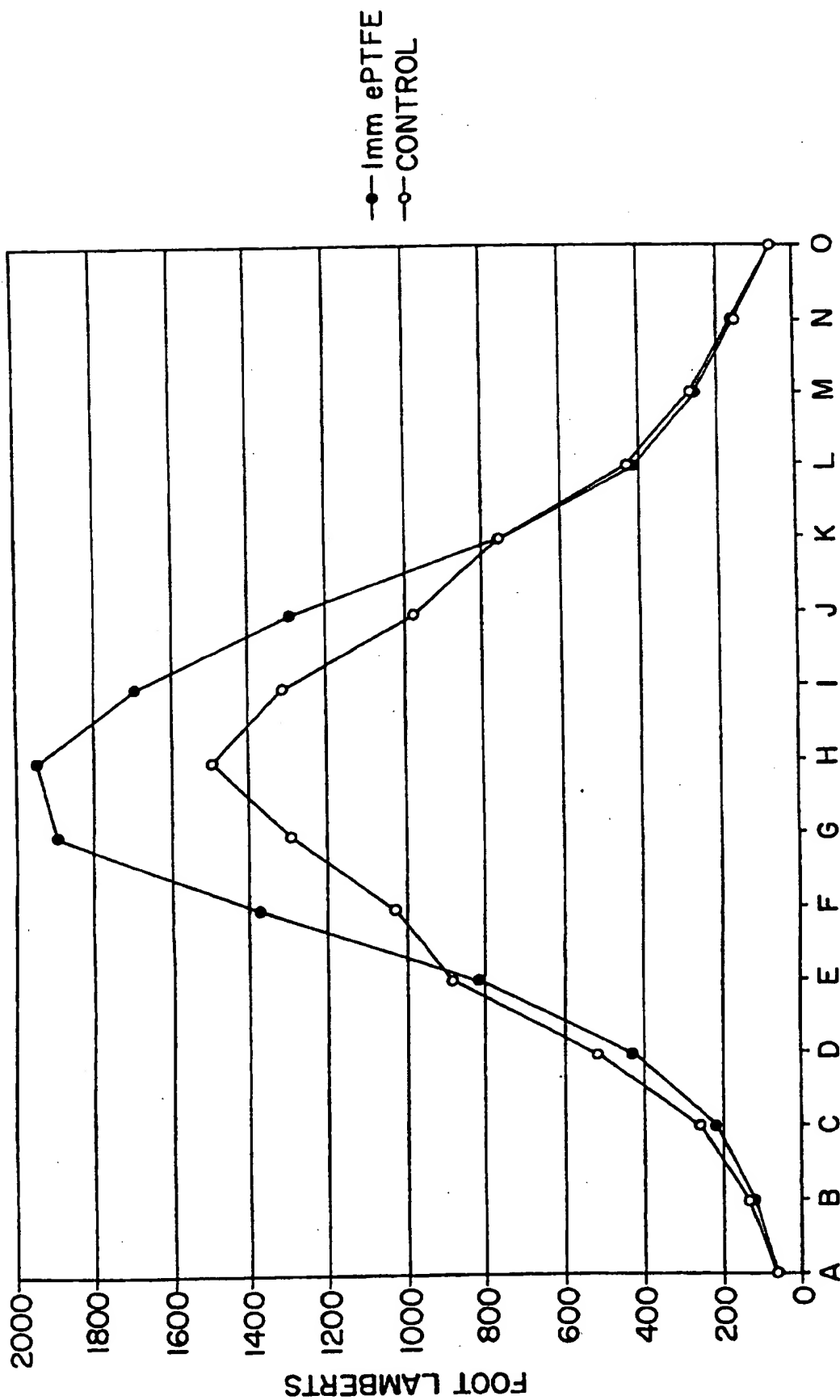


FIG. 15

INTERNATIONAL SEARCH REPORT

In. :onal Application No

PCT/US 97/06111

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F21V7/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 F21V G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 97 08571 A (GORE & ASS) 6 March 1997 see claim 1 ---	1-5
P,X	WO 96 21168 A (GORE & ASS) 11 July 1996 cited in the application see claim 1 ---	1-5
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Further documents are listed in the continuation of box C.

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